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IMPROVED METHODS OF DAIRY WASTE DISPOSAL

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The question is often raised, "Why are milk wastes a serious stream-pollution problem?" Many people in the industry find it hard to believe that the wastes from milk processing do cause damage in a stream. The fact is that as far as the receiving stream is concerned, the waste from a milk plant is just the same as sewage, except that it is considerably more concentrated. Our water use is about 80 gallons per capita each day; this contains about 200 ppm organic solids, about half dissolved and half suspended solids. Milk waste averages about 1,000 ppm, while cheese whey contains 50,000 ppm dissolved organic matter. These wastes have the same effect on the life of a stream as sewage: the normal flora and fauna die off because the bacteria present consume the dissolved oxygen too rapidly for natural reaeration to restore it, and the anaerobic forms, or those with special adaptive mechanisms, predominate. The odor of anaerobic decomposition becomes stronger, and a seriously polluted stream results.

A small milk receiving plant has pollution equivalent to that of a village of 200 people; a medium-size integrated plant (100,000 lbs./day) is equivalent to a population of 2,000 people; and a large plant may be equal in pollution effects to a small city of 10,000 people.

Because all branches of the dairy industry needed better methods of waste treatment, the U.S. Department of Agriculture started research on this problem in 1947. The aerobic processes were investigated because of the high oxygen demand of the waste and the high rate of growth of bacteria on media containing milk. Basic studies made of the oxidation of the mixed aerobic culture that grows in aerated milk waste indicated that a rapid aerobic process could be developed. Determinations were made of the amount and chemical makeup of the cell tissue produced, the amount of oxygen required, and the effect of temperature and oxygen tension. In this way, the necessary facts for pilot-plant engineering studies were established. The biochemical results were as follows:

1. The rate of oxygen uptake by a growing culture containing 1000 mg. of cells, with adequate nutrients, is at least 140 mg. of oxygen per hour. This value is about 20 times that of the saturation pressure of oxygen in water, thus requiring an extremely efficient air supply to maintain aerobic conditions.

2. The minimum concentration of dissolved oxygen needed for maximum rate of growth is 0.3 - 0.5 mg. per liter (ppm.).

3. The total oxygen required for the complete oxidative combustion of one mg. of milk solids is 1.2 mg.

4. Three-eighths (37.5%) of the total oxygen requirement is used during the rapid-growth phase. The remaining five-eighths (62.5%) of the available mutrient materials is synthesized into cell tissue. The only other oxidation products are carbon dioxide and water.

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5. After cell synthesis is complete, the rate of autooxidation (endogenous respiration) falls to about one-tenth or less the rate of oxygen consumption during growth.

6. The rate of removal of organic nutrients during the rapid growth phase is approximately ten times that of the rate of oxidation.

7. These nutrients are stored as polysaccharide constituents of the cells. The polysaccharides are oxidized during the growth of the cells, and the rate of oxidation remains high until these storage carbohydrates are consumed. The maximum storage capacity of the cells is about 50%, i.e., one mg. of cells can store 0.5 mg. reserve carbohydrate.

8. Complete balanced equations for the growth and endogenous respiration reactions were formulated.

9. The rate of growth of the culture at 20°C. is about 65% of the rate at 30°C., while at 10°C., it is 30%. In other experiments, it was shown cultures can be acclimatized or adapted to a temperature of 20° so that a relatively higher rate can be obtained - perhaps 80% of the rate at 30°C.

On the basis of these laboratory studies, a research contract was established for pilot-plant development of a full-scale treatment process. This work was done at the Pennsylvania State University by Professor R. Rupert Kountz and his assistants. A series of excellent engineering studies confirmed and extended the laboratory results.

On the basis of the laboratory and pilot-plant work, a "fill-and-draw" operation was proposed to the industry. The schedule of operation in a great many American milk processing plants is such that nearly all the wastes are released during the morning and early afternoon, over a period of about six hours. Under these circumstances, a continuous-flow system patterned after municipal sewage practice cannot operate in a continuous manner, since the treatment plant effluent can only flow while it is receiving effluent from the processing plant. It is obviously undesirable to have the plant releasing its effluent over the short period in which it is receiving the waste. Any large "spill" or uneven flow would tend to pass through the plant untreated. If the wastes can be contained in the plant until night, a longer period of aeration is available, and a fully-treated waste can be released. A second advantage is that the aeration tank serves as a settling tank. The air supply is shut off soon after the dairy operations cease, the sludge or cell mass allowed to settle, and the supernatant released.

The first industrial waste treatment plant designed on the recommended system went into operation in April 1954 and has operated successfully since then. At present there are nine plants in operation, all directly based on the work at Pennsylvania State University; and many others have been built in which some or all the recommendations of Professor Kountz have been the basis for the design.

Essential features of the recommended design are an adequate supply of dissolved oxygen within the daily aeration period and a high concentration of active bacterial cells. The most successful aeration device tested so far in the contract research has been a water operated venturi ejector. The tank liquid is pumped continuously through the submerged ejector which has an air inlet pipe extending above the surface. The air and water are well mixed and clumps of bacterial cells are broken up. There is less maintenance because the larger openings in the ejector do not clog as readily as do air diffusers of the types often used. Although the power costs are higher than those of conventional air diffusers, the efficiency and ease of operation recommend ejectors. Each unit of the type selected is capable of dissolving about 600 grams of oxygen per hour with a pumping rate of 1850 liters per minute through a 17 mm. diameter nozzle.

In a typical plant, the waste enters the tank from 6:00 A. M. until 2:00 P. M. and is aerated throughout the day with the sludge remaining from the previous operation. At 2:30 P. M., the air supply is stopped, the sludge is allowed to settle for three hours, and the clear supernatant is drained off. Aeration is then resumed.

The amount of cells present is proportional to the concentration of milk solids in the waste, for cell synthesis must continue until it is balanced by the amount of cells consumed by endogenous respiration. Calculations from the theoretical analysis show that the equilibrium cell weight in the system, at 30°C., is 2.5 times the average weight of milk solids received. This value has been confirmed in practice repeatedly.

These facts have permitted Professor Kountz to develop the essential design data if the amount of waste and concentration of solids are known. For a dairy plant handling 100,000 pounds of milk a day, with a small cottage cheese operation, the equivalent milk solids in the effluent might equal 2.5% of the weight of milk received, or 2500 pounds. This waste might be dissolved in 25,000 gallons (200,000 pounds) of water.

The tank volume required would be 1 1/2 times the average daily flow to allow for the sludge held over, variations in daily load, and to provide some height above the liquid at its highest level. The oxygen demand can be calculated on the known activity of the cells and the efficiency of the aerating device, thus establishing the number of aerators required.

In a commercial dairy treatment plant that approaches the hypothetical figures cited, Professor Kountz secured the following typical operating data.

<u>Typical Operating Data</u>

Waste volume (8 hr.)	25,000 gal.
BOD of influent	1,660 ppm.
BOD of effluent	72 ppm.
BOD reduction	95.7%
Tank volume	37,500 gal.
Sludge volume	20-30%
Normal Temperature	30°C
Dissolved oxygen	0.6-3.5 ppm.

Some large plants are on a 24-hour operation schedule. A fill-and-draw system is not applicable to them. Moreover, some regulatory agencies require discharge over the entire 24-hour period. A continuous flow system has been studied extensively at Pennsylvania State University and a number of installations are in successful operation. However, the aerated sludge is difficult to settle, especially during periods of rapid growth, and in some plants causes a problem. Further research on this phase and on more efficient means of aeration is planned. Cheese whey, which contains about 5% organic solids,